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SEPTEMBER 1989

PROJECTED IMPACTS OF THE THREE GORGES DAM ON THE BAIJI, *Lipotes vexillifer* AND THE NEEDS FOR CONSERVATION OF THE SPECIES

By

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ADMINISTRATIVE REPORT LJ-89-23

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VEXILLIFER, AND NEEDS FOR CONSERVATION OF THE SPECIES

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Chinese version written in 1987

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Abstract

After the completion of the three Gorges Dam, the clear water released from the dam will severely erode a long stretch of the river bed in the middle reaches of the Yangtze River. The force of the flow will cause it to be straight and centered in the old river's course, thus increasing siltation of small river branches and reducing the size of sand beaches along the shores. The existing large counter-current areas in sections where serious erosion occurs will disappear or shrink in size. Consequently, these areas will not be suitable for the baiji's existence. We theorize that the river section from Yidu to Ouchi (about 200 kilometers) will lack the proper ecological environment for the baiji's existence and that in the section from Ouchikou to Chenlingji the population will be reduced by 41% to 71 % due to the environmental changes. The section from Luoshan, Honghu County to Xintankou (about 135 km) where the baiji occurs now in dense concentrations will experience a large increase in boat traffic that will lead to increased incidental kills. If we do not take proper and effective protection measures now, the species will be in increased and imminent danger of extinction.

Tien'ezhou, an old oxbow of the Yangtze at Shishou in Hubei Province, possesses excellent natural conditions for the baiji. The water is fresh and clear and fish are abundant. We predict that the river course here will be stable with operation of the Three Gorges Dam. Due to the release of clear water from the dam, the degree of siltation at the upper and lower mouths of the old waterway will be reduced. If we modify the upper and lower mouths of this section, we can effectively keep the dolphins from escaping once we bring them in.

This water area can be established as a center for the baiji's reproduction and protection. We can bring in the baiji in groups to live in this reserve. The investment in construction would be very small, and the results would be very beneficial to the baiji's reproduction and protection.

INTRODUCTION

Very little had been known about the baiji's ecology and status until the Academia Sinica established its baiji research team in 1978 and began observing the dolphin in its habitat in the wild. For seven years the team observed and studied the baiji, and we now understand its status, habitat and group activity patterns.

The baiji lives in the main channels of the middle and lower reaches of the Yangtze. About 300 dolphins are distributed in 42 groups along the 1400 kilometers of the river from Yidu to Hekou. Economic development along the middle and lower reaches of the river have disturbed the balance of the baiji's natural habitat. The environment is deteriorating rapidly, with implications for the baiji's survival. The lack of understanding by the public about the baiji's plight leads to many incidents of capture and death. Based on the population count, the baiji is in imminent danger of extinction (Chen Peixun et al., in press).

After leaving the Three Gorges, the Yangtze enters a large plain. The river suddenly widens at this point and flows smoothly and softly, allowing sand and mud to settle and form many sand islands and sand beaches (Chen Peixun et al., 1980). These beaches and islands extend toward the center of the river, blocking the flow of the current to form many large areas with countercurrents and eddies. Each of these areas consists of several currents with different hydrologies and conditions. Water flows freely here and fish gather, providing a good feeding and resting area for the baiji. Near the countercurrent areas there are many deep trenches where organisms thrive in the organic sediment, providing food for the fish that the baiji feeds on (Hua Yuanyu et al., in press).

The baiji's group activities are highly associated with these countercurrent areas. The dolphins often swim against the slow current along the sand beaches and islands in water about 5-9m deep. They remain for a long period of time in one of the countercurrent areas and then move up or down the river to another such area (Hua Yuanyu et al., in press). The current often changes the depth of the trenches and the height of the beaches and islands. In general, the shallow beaches and islands become built up when the Yangtze floods and are washed away during the dry season, while the deep trenches are affected in a reverse manner. After many years' observation, we discovered that when the countercurrent areas move because of changes in water conditions, the baiji move accordingly. The farther the countercurrent areas moved, the farther the baiji moved (Hua Yuanyu et al., in press).

The clear water released from the Three Gorges Dam after its construction would wash away much of the Yangtze's bottom sediments over a long distance on a continuing basis. The water would flow straight down the center of the river channel and

cause siltation of branch rivers and shrinkage of the sand beaches and islands. The countercurrent areas would either disappear or diminish in size. What would be the effects of these changes on the baiji?

In order to understand the effect of the Three Gorges Dam on the baiji, we conducted full investigations twice, first in the winter from November 1985 to February 1986 and second in the spring from April 1986 to June 1986. We put emphasis on the hydrology of the river, the riverbed, the baiji's distribution and its daily activities along the main stream of the middle and lower reaches of the river (Yichang to Jianyang). In this article we present our analyses of the probable effects of the construction of the dam on the baiji based on the results of these two investigations, information gained from 7 years' observations of the habitat, and the characteristics of the river course of the middle and lower reaches of the Yangtze.

1. THE BASIC CHARACTERISTICS OF THE MIDDLE AND LOWER REACHES OF THE YANGTZE RIVER COURSE AND THE MAIN SECTIONS WHERE BAIJI ARE DISTRIBUTED.

The middle and lower reaches of the river are composed of stretches of wide riverbed alternating with narrow riverbed. The river course is complicated and ever changing. It takes many forms: straight, straight and divided, winding, and winding and divided (see Figure 1). The divided waterways rejoin and redivide again in varying combinations. The straight sections are where the riverbed is narrow. The straight and divided sections occur at the upper and lower ends of the eastern narrow stretch of the river. The winding sections are in areas where the riverbed is wide. The river course is winding and divided in the areas where large or small lakes are found next to the river and where small rivers merge with the Yangtze (Yan Qinshang and Zheng Zhaoxuan, 1985; Academia Sinica, Institute of Geology, 1985).

The section from Yichang to Chenlingji is considered unstable. It contains both straight and winding stretches. The straight portions have uneven beds that resist the scouring force of the current, leading to sand beaches and islands spread along both shores. The tendency of the river to meander is restricted by the banks; this prevents the beaches from becoming firmly established. They move slowly downstream. The river in the winding sections is not restricted by the shores; thus it swings back and forth on the wide bottom of the overall river course. Concave sections of the banks are scoured to form deep trenches, while silting at protruding sections of the shore leads to fully developed beaches and islands.

There are many high points on both sides of the river at and below Chenlingji. The river force here is stable. The high points along the Bianjian section are formed by hills and bedrock. The obstacles force the river course to be winding and

divided, and siltation is intensified. This condition permits the sand islands in the center of the river to be well-developed. They are broad and high. The river splits into two or more courses around these sand islands and flows unimpeded. Large countercurrent areas are formed near the islands. In the section where many high obstructions stand facing one another, the river course is straight and divided. The sand islands in this section are mostly in embryonic form; they are low and small or nearly nonexistent.

Our preliminary statistics show that there are about 120 sand islands and 40 beaches along the middle and lower reaches of the Yangtze. We made sightings of baiji at 42 of these places; the total count was from 293 to 297 (Chen Peixun et al., in press).

The beaches and islands where baiji were not sighted are either not well formed or nearly nonexistent. They are mainly concentrated along the straight river sections. The sand beaches along these shores are narrow and unstable. The waterways around the sand islands are either very small or dry. The sand islands themselves are cut off and some of them are connected with the shore. Their common hydrological characteristic is that no large countercurrent areas formed around them.

The sand islands and beaches are well developed at the places where baiji were sighted. These islands and beaches are distributed mainly in the winding or winding-and-divided sections of the river. In these winding sections, deep trenches and sand beaches face each another for a long distance. The beaches are wide in the curves of the river. Because of slowing of the current, siltation is intensified and the river is divided by one or more sand islands into many waterways. The current flows freely in each of these waterways. The main hydrological characteristics of these sections are that large countercurrent areas are formed near the islands and sand beaches and that countercurrent areas are connected with deep trenches.

From Yichang to Jiangkou the river is basically straight, with only one small winding section. In January 1986, we searched back and forth along the 30-km section between Yichang and Yunchi and failed to spot any baiji. However, we did sight baiji at four spots between Yunchi and Zhijiang. There are 10 large bends in the river between Ouchikou and Chenlingji, and we sighted baiji in these areas. On the basis of our observations, the baiji's density is the lowest in the section between Yichang and Jiangkou, about one per 14.3 km. The highest density is in the section between Ouchikou and Chenglingji, where the average is one per 4.1 km. This shows that the baiji prefers the winding portions of the river.

The lengths of the straight portions are different for the river sections between Chenglingji and Jiujiang and between Jiujiang and Jiangyong. The averages are about 30.2 km and 295.0

km, respectively (Yangtze Valley Programme Office, Hydrology Division, 1983). However, the density of baiji varies little; it is about one per 5.6 km and one per 5.1 km, respectively. Since there are 10 winding-and-divided sections between Jiujiang and Jiangyong and only 6 between Chenglingji and Jiujiang, this demonstrates that the baiji prefers to live in winding-and-divided sections. In fact, of the 42 sand beaches and islands where baiji are found, 28 are in the winding-and-divided sections of the river. The baiji here comprise about 72% of the total population. The rest of the beaches and islands are distributed along the straight-and-divided and gently curved sections of the river (Figure 1).

During our investigations, we have not seen any baiji in the straight sections of the river, but we have often encountered them in the winding and winding-and-divided sections. Therefore, we believe that the winding sections and winding-and-divided sections are the most suitable habitat for the dolphin.

2. Effects of the Three Gorges construction on the baiji population.

Fishermen at Yichang report that they saw baiji in the Yichang section of the river before the Gezhouba Dam was constructed but have not seen any since the completion of the dam. Based on our observations, the baiji's upper distribution now ends in the Yidu section. The main reason for this is that the riverbed has a depth of about 4 m between Yichang to Yunchi and is very irregular. Large countercurrent areas are not present and therefore this section is not suitable for the baiji. At Yidu the river is winding and the countercurrent areas have sandy bottoms, which provide somewhat suitable conditions for the baiji. However, due to the marginal nature of the habitat, the group of dolphins living here is small.

If the Three Gorges Dam started operation, the clear water released from the dam would start a new process of riverbed formation. The water would scour the riverbed for a long distance. The changes in the riverbed would tend to be desilting and merging of channels, deepening of the river and stabilizing of the current force (Tang Richang, 1985). What would be the effect of these changes on the baiji?

2.1 The baiji's distribution area would shrink about 200 km.

In the section between Gezhouba and Jiangkou (110 km), the riverbed is stable, the resistance against scouring is strong, and the riverbed is covered with rocks. The layer of alluvial sand is about 2.7 meters deep. After years of scouring caused by the dam, the river would reach some balance. The large countercurrent areas would disappear, except in a few small areas that contain sandy bottoms. Most of the rest of the river would have a rock bottom. Silt would not accumulate on the riverbed and sandbars, and turbidity would decrease.

From Jiangkou to Ouchikou (about 135 km), the river bottom is composed of alluvial sand. Sediment-free water from the dam would scour the riverbed severely. Measures against erosion have been taken along outside banks in curves of the river, especially in the Bingjianjiang section, where stone levees have been under construction for the past 30 years. Here the erosive force of the river is under control along the banks. Therefore, the water would mainly erode the riverbed, branch rivers would be blocked by silt, and the main channel would run straight down the center of the old broad rivercourse. The sand beaches and islands would change shape permanently, and large countercurrent areas would disappear. The upper boundary of the baiji's distribution would move downstream to about Ouchikou, a distance of about 200 km. The 8 groups of dolphins (19% of the total number of groups), or 33-34 individuals (11.3 - 11.5 % of the total population) that presently live in this section of the river would be affected greatly (Figure 2).

2.2. The baiji's population size would decrease in the river section from Ouchikou to Chenlingji.

The Xiajinjiang river section was originally an excellent habitat for the baiji. The banks of the river here are being changed drastically. Although already reshaped by an engineering project which started in 1960, the river would undergo even more change after construction of the dam. There would be serious scouring that would lead to deepening of the main channels and make the riverbed irregular. Points of land that project into the river would be eroded away, and some of the sections of bank would collapse. Branch rivers would be silted up, and the sand beaches and islands joined together. The wide beaches along the shores would disappear, and large countercurrent water areas would shrink in size consequently. Suitable habitat for the baiji would be limited to two sections: from Ouchikou to Yichang and from Yichang to Jiangkou. The baiji's population size in these sections would gradually decrease (Figure 2). At present, there are 5 groups totaling 38 baiji living in this section of the river. We estimate that the population after the Three Gorges Dam commences operating would be at least 11, if we use the lowest density figure of one dolphin per 14.3 km from the section of the river from Yichang to Jiangkou as the calculation base. We would get an estimate of 21-22 baiji if we used the density estimate for the section from Yichang to Ouchikou of one dolphin per 4.1-4.3 km. Thus the baiji population would be reduced by 16-27, or 42.1-71.1% of the present size for the region.

2.3. Incidental kills of baiji would increase in the river section below Chenlingji.

We have gathered death statistics for the baiji for the period 1979-1984. Based on examinations of 33 specimens, 45.5% of the deaths were caused by rolling hooks, of which 70% occurred in January to March and the rest November and in April. Deaths

caused by propeller made up 6.1% of the total and occurred in the months of January and February. Beachings accounted for 18.2% of the deaths; these occurred from January to March. All of the human-related deaths took place in the dry season.

If operation of the Three Gorges Dam began, water level in the river would be under control and floods reduced drastically. The water would be maintained at medium levels for long periods of time. In the dry season, the rate of flow would be increased. This would compensate for the reduced water level due to deep scouring of the river bed. Beachings of dolphins might diminish. Incidental deaths caused by fishing activities might also be reduced.

Although the baiji can rely on its advanced acoustic system to avoid noise, it is endangered by the ever increasing vessel traffic and other human activities along the middle and lower reaches of the river. For example, in February 1982 in the river section near Jianliai in Hubei Province, the two large Dongfanhong ships #51 and #54 were approaching from different directions. A baiji unable to dodge the approaching boats got caught between them in shallow water near a beach and was killed by a propeller.

Once the river water level increased, the current would run more slowly and evenly. Some of the lower sand islands would be submerged. Others would shrink in size and possibly disappear altogether due to siltation. The river section from Chenglingji to Jinkou would have increased siltation and beach development. Large countercurrent areas would increase in number and become relatively stable. Because the baiji's overall habitat would be reduced over the length of the river, its activities would be heavily centered in certain sections of the river such as this. The river sections where baiji gather in numbers are also places where fish thrive. The fish attract fishermen. With the increased fishing activities in these areas, incidental deaths of dolphins would inevitably increase.

The increased river depth would improve conditions for vessel traffic, and in consequence the river shipping industry would flourish. This would bring devastating threats to the baiji's survival. We have compared the seriousness of the deaths of dolphins caused by propellers between the middle and the lower reaches of the river. The shipping traffic is much heavier in the lower reaches. From 1979 to 1985, there were 10 vessel-collision deaths in the lower reaches (32.2% of the total toll of 31) (Zhou Kaiya et al., 1986). There were only 2 such deaths in the middle reaches of the river (6.1% of the total). Larger tonnage boats are increasing in number. This generates more traffic on the river. The probability of a baiji being killed by propeller is increasing. The river section from Luoshan to Xingtankou in Hubei Province (135 km) has the densest population of baiji. There are 3 large groups totaling about 40 dolphins in this area

(14.8% of the total population). Accidental deaths of dolphins would increase in this area due to the heavy traffic. Protective measures must be taken here to conserve the baiji.

2.4 Water temperature shifts might affect dolphin growth and reproduction.

According to the Water Resource Protection Agency, a 150-meter dam would not produce a reservoir in which thermal stratification would occur. However, a 180-meter dam would hold water in the reservoir longer and lead to stratification. Water released from the dam would be cooler than the natural river water during periods of rising temperature and warmer during low-temperature periods. After construction of the dam, the river might not attain the normal April temperature until a month later. March-April is the most active mating season for the baiji. They give birth in middle and late April. We need further investigation and data to determine whether these temperature shifts might adversely affect growth and reproduction in the dolphins.

2.5. There might be baiji living in Dongting Lake once again.

The baiji was once present in Dongting Lake. The environment became unsuitable due to siltation and changes in the lake's hydrology. In recent years, a few baiji have followed fish into the east end of the lake during the flood season and followed the fish back to the main river again during the dry season. Those which did not leave the lake in time were often killed accidentally by rolling-hook fishing gear. According to the Junshan Natural Conservation Bureau of Hunan, there have been recordings of unnatural deaths of baiji in 1976, 1978, and 1981 at the east end of the Lake. After construction of the Three Gorges Dam, the depth of the lake would increase due to long-term scouring and siltation. The environment would be changed for the better for the baiji, and it might permanently inhabit the lake once again.

2.6. More study is needed to understand the social relations of the baiji.

After the construction of the Three Gorges Dam, the range of the baiji would decrease. How might the population structure be changed? How would the new social balances be established? Are baiji territorial? Concerning those that presently live between Yidu and Ouchikou: would they die because they could not adjust themselves to the new changed environment? Or would they move into Dongting lake or farther down the river? If they moved to the lower areas, would the local groups tolerate them, or would they be aggressive toward them? These are the questions to be answered.

3. Conservation strategy.

The baiji population is small and its reproductive rate is low. The calving interval is about two years (Chen Peixun et al., 1985). Until a full conservation policy is in force, individual baiji will continue to be harmed accidentally by people. Therefore the population will continue to decrease, especially if the producing animals are killed. After the completion of the Three Gorges Dam, the living area for the baiji would be reduced even more. The ever increasing river traffic adds more threats to the baiji's existence. For all these reasons, the conservation of the baiji and protection of the natural resources over the 1400 km of the middle and lower Yangtze River is a very tough task. We have studied the baiji's ecological environment and behavior and now understood the main threats to its existence. Considering the present population status and the probable effects of the Three Gorges Dam, we propose the following measures for the baiji's conservation:

1. Establish protected natural reserves on sections of the river.

There are two sections of the Yangtze, from Luoshan to Xingtankou at Honghu in Hubei Province and from Anqing to Heishazhou in Anhui Province, where the river is wide and open and its bottom gently sloped. The shores along these two sections are siltation plains, and sand islands are present in great number. The lengths of these two sections together comprise about 1/5 of the total length of the middle and lower reaches of the river. The number of baiji in these sections is about 1/3 of the total population. We propose that protection offices be established along these two sections of the river and that full-time personnel be assigned to patrol the river in order to protect the baiji's natural habitat, to set markers and signs in the large counter-current areas where baiji frequently occur (in order to limit or restrict any fishing activities), to monitor river traffic speed, to stop any deliberate killings and to reduce incidental deaths of the baiji. In addition to the above mentioned measures, we would propose to put emphasis on ecological study of the baiji in these reserves in order to speed up the acquisition of knowledge that may allow us to bring about artificial increases in dolphin recruitment (see below).

2. Select water areas with superior natural conditions and establish several baiji centers for reproduction and conservation.

The baiji's population is rapidly declining because of rapidly increasing river traffic and the fishing industry. It is not enough to just establish conservation offices to protect its natural habitat; we still need to move some of the individual baiji or a colony of baiji into an environment under human control in order to increase the reproductive rate.

In the past, the current in the section between Ouchikou and Chenlingji was not stable; the river course changed often. At present, some of the old channels become active waterways during the flooding season and some become oxbows that are separated from the main river. In about 20 km of the lower end of the river at Shishou city in Hubei Province, there is a natural old waterway named Tien'ezhou (Figure 3) where baiji used to occur. It has formed a half closed natural water area since 1972. This waterway circles Tien'ezhou Island and is about 21 km long. There is no pollution source, and deep areas are mixed with shallow areas. There are two large deep trenches, where the water is about 20-25 meters deep in the summer and 15-20 meters deep in the winter. The volume of the water at the lowest water level is 2000 "Qin" [a unit of area, = 6.6667 hectares]. At the present the upper mouth of the waterway is silting up fast, and about 200 "Qin" are covered with growing reeds. The oxbow connects with the river during the flood season only. At its lower mouth, about 300 "Qin" of reeds have been planted, and there is a 2-km long winding and shallow stretch of water. It splits at Tien'ezhou Island and is separated from the main river during the dry season. The shallowest section of the upper part of the oxbow was measured in August 14, 1987 to be 1 meter deep at the highest water level. At the lower mouth, there is a dirt dike about 30 m long and 3 m high. Behind the dike, the water is shallow for about 500 meters. The highest water level in the shallowest area is 5 meters. In this old waterway, fish and other natural resource are abundant. Most of the fish are river or lake fish and weigh about 100-700 gm. Fishermen fish here all year round. Based on the daily food consumptions of 7.5-10 kg for "Qiqi", a male baiji in captivity, we are sure that this water area would provide ample food for 20-25 baiji year-round. All we would have to do is to set up barrier nets or bars at the lower mouth. More nets and bars would be added during the flooding season to prevent baiji from escaping.

Protective measures have been taken recently in order to strengthen the banks at Shishou, making the current smoother and steadier. If the Three Gorges Dam began operation, the current would be even more smooth and steady. Due to the low turbidity of the water released from the dam, the river would have a higher capacity than now for carrying sand, and this would slow down the silting process at the upper and lower mouths. During the dry season, the water level would be higher than previously; the old waterway would not become completely separated from the main river. The old waterway at Shishou is an excellent natural environment similar to the baiji's natural habitat. It is more secluded and quiet than the main river, thus more suitable for baiji for reproduction and raising the young and can be easily managed by in order to carry out research. Therefore, minimal modification and some measures to prevent siltation at the upper and lower mouths of the old waterway can make it a center for reproduction and conservation. There are a few other similar old waterways, for example, the Chewan old waterway in Jianli County, etc. In addition to these sites, a by-river river at the lower

end of the Chenlingji section in a winding-and-divided part of the river could be selected for use as another such center for reproduction and conservation. Moderate modification and addition of bars to the mouths of the by-river would be required. Construction of semi-natural reserves at Tongling in Anhui Province and at Yuezhoujiajiang is in process.

If we can carry out the measures detailed above, we can not only protect the existing baiji but also increase reproduction in the population.

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Table 1. Distribution of baiji groups, with number of individuals for each group. Data collected from November 23, 1875 to February 2, 1986. Distance is from mouth of the Yangtze River.

	Section No. (no.)	Sandbar Name	Distance Name	River-course (km)	Baiji Type
1.	Yichang	Nanyangji	1633	Winding	2
2.	"	Guanzhou	1601	Winding & divided	2
3.	"	Yaugang	1578	Winding (slightly)	3
4.	"	Bamutan	1563	"	2
5.	"	Erjingzhou	1488	Winding	3
6.	Ouchikou	Nanwuzhou	1473	Winding (slightly)	5
7.	"	Tienxingzhou	1453	Winding	8
8.	"	Sanhezhou	1433	"	8-9
9.	"	Wumingzhou	1406	"	6
10.	"	Fangjiajia	1383	"	8
11.	"	Damazhou	1345	"	8
12.	Chenlingji	Baxianzhou	1290	"	7
13.	"	Zhuoyuzhou	1275	"	9
14.	"	Changwangzhou	1228	Straight & divided	18
15.	"	Fuxingzhou	1163	Winding & divided	16
16.	"	Tudizhou	1133	Winding	7
17.	"	Tuanzhou	1123	Winding & divided	6
18.	"	Baishazhou	1045	Straight & divided	7
19.	"	Muezhou	995	Winding & divided	3
20.	"	Luohuzhou	965	" "	5
21.	"	Daijiazhou	920	" "	8
22.	"	Guniusha	890	Winding (slightly)	5
23.	"	Xingyuzhou	873	" "	3
24.	Jiujiang	Huanglianzhou	847	" "	7
25.	"	Xingzhou	820	Winding & divided	13
26.	"	Zhangjiazhou	772	Straight & divided	10-12
27.	"	Gupaizhou	718	" "	7
28.	"	Yudaizhou	680	Winding & divided	5
29.	"	Guanzhou	651	" "	9
30.	"	Jiangxinzhou	620	" "	6
31.	"	Yubanzhou	602	" "	10
32.	"	Guanshuizhou	578	Straight & divided	10
33.	"	Heyuezhou	552	Winding & divided	7
34.	"	Chendezhou	530	" "	9
35.	"	Heishazhou	476	" "	10
36.	"	Jiangxinzhou	400	Straight & divided	7
37.	"	Meizezhou	350	" "	5
38.	"	Baguazhou	330	Winding & divided	7
39.	Jiangyin	Shiyezhou	278	" "	16-17
40.	"	Fuanzhou	135	" "	6
41.	"	Tongzhousha	80	" "	5-7
42.	Hekou	Baimaosa	20	" "	5-7

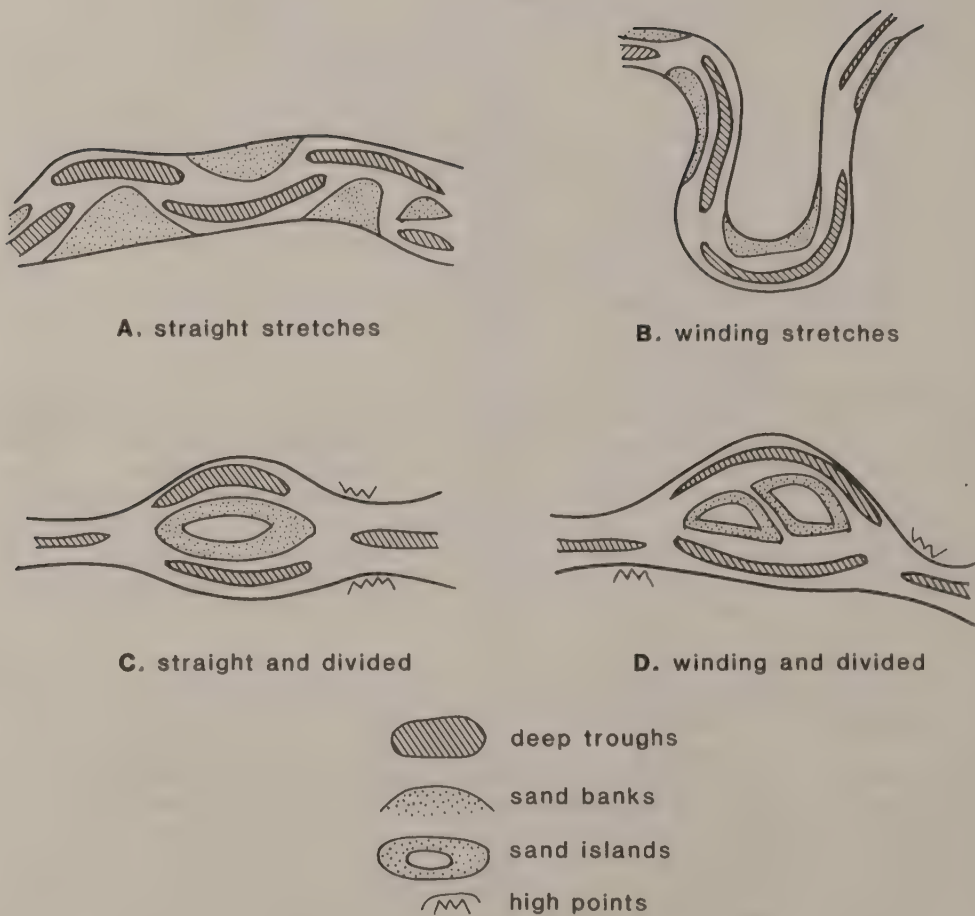


Figure 1. Variation in the bed of the Yangtze River.

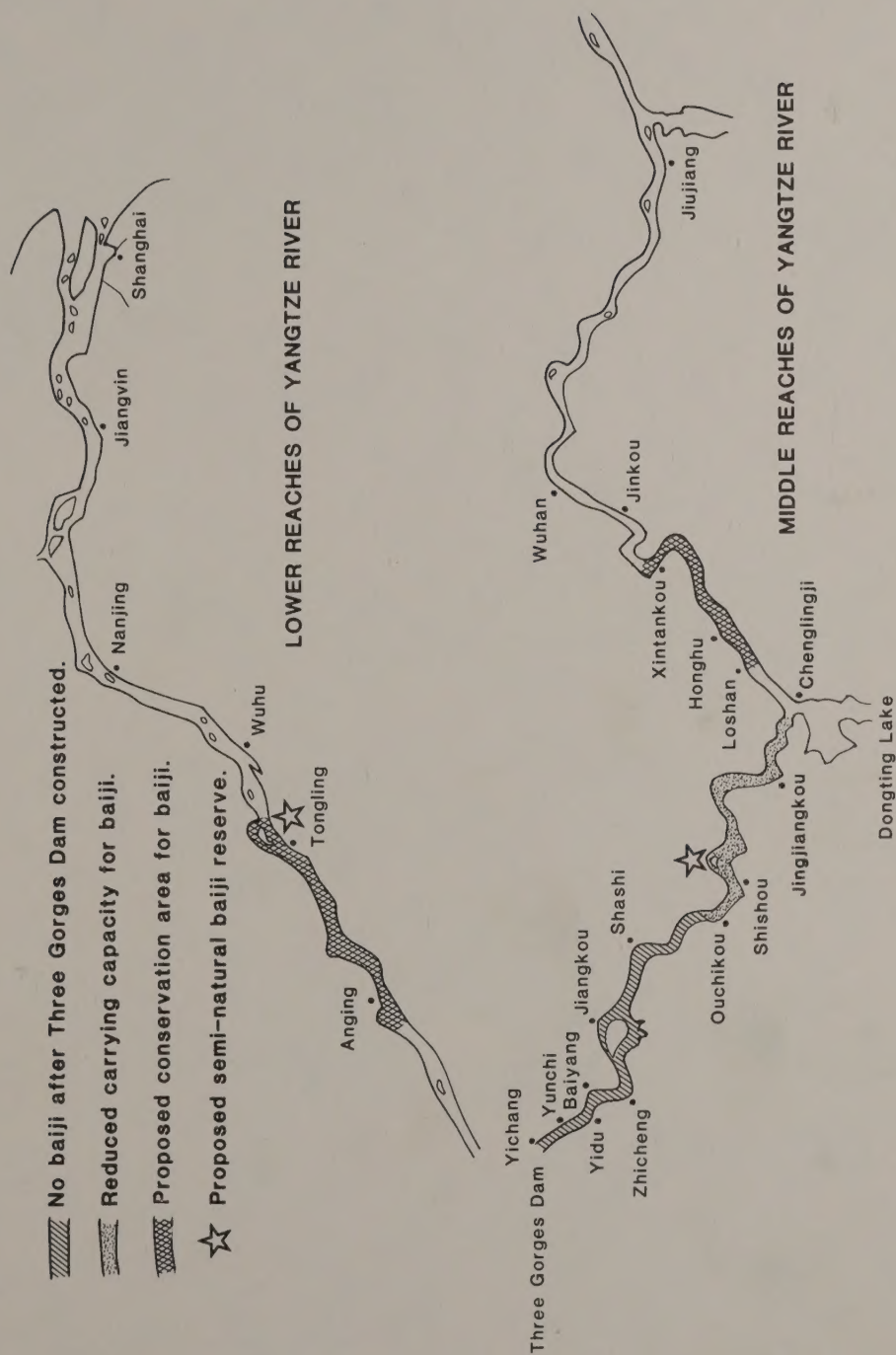


Figure 2. Projected effects of the proposed Three Gorges Dam on the habitat of the baiji.

